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AMS Report 1263

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**FINAL REPORT OF THE REVIEW
AND EVALUATION OF THE WORK
OF FRIEDRICH O. RINGLEB**

D. C. HAZEN

AMS Report No. 1263

December 1975

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SUMMARY

➤ A review of the published works of Dr. F. O. Ringleb and of unpublished notes and data taken from his files at the time of his death was conducted with the intention of identifying any topics which might warrant continued investigation. Emphasis was concentrated on the contents of 52 folders and a large 4" x 6" card file. These items were carefully reviewed and inventoried. Although much of the material had certain historical interest, most of the material examined had either been utilized in the preparation of Dr. Ringleb's published works, or in direct support of projects then current within the Naval Air Engineering Facility. It was concluded that, although there is a need to continue to pursue Dr. Ringleb's constant search for understanding of the basic nature of vortex flows and his concept of the control separated flow by means of trapped vortices, none of the material examined pointed to the need for a continuing research program of a specific nature. ✓



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INTRODUCTION

Brought to this country by the U. S. Navy shortly after the end of World War II, Dr. Ringleb worked at the Naval Air Engineering Facility in Philadelphia until the time of his death in 1966. His interests were wide ranging, but he is probably best known in the field of fluid mechanics for his work with various types of vortex flows, his extensive use of flow visualization techniques and his utilization of classical methods of conformal mapping to attack non-classical problems. Because of his association with the Naval Air Engineering Facility, he became intimately concerned with catapult and arresting gear design, particularly in the area of cable dynamics, a field to which he made a number of significant contributions.

Since Dr. Ringleb had been associated with such a broad spectrum of problems of concern to the Navy, there existed the possibility that some of his ideas had not been fully developed in his published work. As a consequence, this examination and evaluation of the technical files found in his office after his death was undertaken with an eye to determining whether there existed elements of his work that warranted the development of further research programs.

What emerged from the study was the picture of man possessing a keen physical sense coupled with a considerable analytical power. To those who knew him, it was no surprise to find that many of his files related to personally developed proofs of accepted theorems, for he was ever on the alert for something overlooked or erroneously taken for granted. For most of the physical phenomena he observed in his smoke tunnel or with his other flow visualization techniques, there were presented analytical explanations.

Given the period that has passed since his death, as well as the fact that his productivity was severely hindered from 1963 onwards by ill health, it is probably not surprising that this study of his papers did not reveal an area warranting the development of a program of further research. Nonetheless, there is still much to be learned from the examination of his smoke and water photographs. His published papers still form excellent reference material for current investigators. A number of the problems he examined, such as the flow around carriers, poor stack flow and ineffective diffusers continue to be of concern today. One suspects their eventual solution will owe a lot to the pioneering work of Dr. Ringleb.

DISCUSSION

As a first step in this project to review and evaluate the works of Freidrich O. Ringleb, a literature search was conducted. In addition to the unpublished materials received from the Naval Air Systems Command, an effort was made to collect and read as much of his published material as possible. The following sources were consulted:

1. Defense Documentation Center.....No Citations
Classified TAB Indexes (1960 to date)
2. NASA Classified STAR.....No Citations
Indexes (1957 to date)
3. Engineering Indexes.....Citations Included in
(1946 to date) Table I
4. Physics Abstract A.....No Citations
(1946 to date)
5. International Aerospace Abstracts.....Citations Included in
(1962 to date) Table I
6. NASA STAR.....No Citations
(1962 to date)
7. NACA Technical Publications Index.....No Citations
(1949 to 1962)

8. Dept. of Commerce Technical Translations...No Citations
(1959 to date)

In the effort to collect these published works, Dr. J. R. Vinson, Professor and Chairman of the Department of Mechanical and Aerospace Engineering of the University of Delaware was most helpful.

Table I contains a list of the 53 citations it was possible to discover from the above sources. It is known that in addition to these, Dr. Ringleb conducted many other studies, sometimes reported verbally, sometimes with just a collection of flow visualization photographs, with but a page or two of text but, with the exception of some elements of these that are included in the unpublished material obtained from the Naval Air Systems Command, no extensive effort was made to trace records of these studies. Four major references found when going through the folders are listed separately in Table I. Other notes and memoranda are noted in the inventory of the folders presented in Table II.

The first of the unpublished sources to be investigated was the 4" x 6" card file. Containing more than 600 cards, this proved to be a collection of a variety of items. The greatest percentage of the cards were devoted to development of specific mathematical functions, particularly conformal transformations and gas dynamic relationships. In addition, there were some cards grouped together as if they had been

used as notes in verbal presentations, but since they simply related to basic mathematical and flow relationships, outside of speculating that they were employed in a discussion relating to vortex flows, little else could be gained from them. A portion of the file was devoted to report and drawing references including Dr. Ringleb's own publications and was of use in compiling Table I. Tucked into the back of the file were a number of poloroid smoke flow photographs. Most of these were identified and augmented by larger photographs from the material later examined in the folders. The photographs are inventoried in Table III.

In undertaking a review of the folders, an initial effort after scanning the material was made to group them by general topic area. As more detailed reading of the material proceeded, however, it was found that there was so much intermingling and cross referencing of material that this was truly impractical. As a consequence, Table II, the inventory of the files, was prepared utilizing the originally determined numbering system with the intention that the text of this discussion would call out the file numbers involved with each topic. Thus a given file may be referenced several times under different topical headings.

With the exception of removing duplicate copies of printed material in order to reduce the bulk of the folders, nothing other than the photographs were taken from them. As there appeared to be no particular

system of placing the material in the folders, it was freely rearranged in order to produce as coherent a picture of the topic as possible.

Because smoke tunnel and other photographs were scattered throughout the folders, sometimes in a seemingly random manner as if they had been simply shoved into the most convenient folder at the moment, these were removed and collected in a separate folder. Table III is an effort to tabulate and identify this material.

a) Smoke Tunnel - File No. 1

Having early in his professional career worked with A. M. Lippisch, Dr. Ringleb greatly appreciated the value of smoke flow visualization and it was under his urging that the flow visualization facilities at Princeton were created. To meet the need of his own investigations, he constructed in his laboratory in Philadelphia a three dimensional tunnel having a test section measuring 5' x 5' x 8' and capable of airspeeds from 3 to 10 feet per sec which provided useful Reynolds Numbers up to 7.5×10^5 based upon model length. Completed in 1960 and described in Reference 43, Table I, the usefulness of this tunnel lay in the fact that the flow could be visualized by three dimensionally spaced smoke filaments which originated in the free stream. Much of the work Dr. Ringleb conducted after 1960 was based on this excellent facility.

- b) Vortex Motion - Files 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12,
14, 26, 34, 38, 44, 48, 50, 51

In his youth Dr. Ringleb had been an enthusiastic mountain climber. Once when stuck on a ridge during a snowstorm, he observed the gradual accumulation of snow on the leeward side in the separated region of the flow until a snow cornice formed and a vortex was created below its lip, which acting as a roller bearing, carried the flow about the edge thereby eliminating the separation. Interest in the phenomenon never left him and it was the basis for his suggestion that led to the cusped diffuser in the Princeton 4' x 5' wind tunnel described in Reference 25, Table I.

As he continued to amass flow visualization data, he concluded that vortex phenomena were fundamentally three dimensional and not really amenable to the two-dimensional treatment of Reference 29, Table I. He continued to investigate vortex flows and to urge their study not only as a method of controlling separation but also as an explanation of flow phenomena about such diverse structures as buildings, submarine hulls, aircraft carriers and smoke stacks. As one can see by looking through the referenced files as well as References 25, 26, 27, 29, 30, 35, 38, 40, 41, 42, 44, 45, 46, 48, 49, 50, 51, 52 and 53 of Table I, Dr. Ringleb considered the understanding and prediction of vortex flows as fundamental to the understanding and control of a wide range of flow phenomena. One feels that he

would have taken a very active role in the recent work on aircraft wakes and leading edge vortex stabilization had he lived.

c) Smoke Stack Control - Files 4, 5, 6, 7, 38

During the course of his work Dr. Ringleb investigated a number of methods of controlling the smoke from ship stacks. One of his early studies suggested the use of the ring vortex for this purpose, an idea that still resurfaces from time to time, but was discarded because of the power and complexity involved. His most impressive work resulted in the so-called "cyclone" generator approach of which there are a number of photographs cited in Table III. Recently this concept has been adopted by Grumman Aircraft as a source of suction for a specialized windmill they have under development. Being a convenient and effective way of creating a trapped vortex, this device will undoubtedly find many other uses in the future.

d) Airflow About Carriers - Files 6, 7, 8, 9, 10, 11, 12

In a series of outstanding smoke tunnel investigations Dr. Ringleb not only showed the nature of the deleterious effects produced by the vortex flow existing around an aircraft carrier, but showed how changes of geometry could substantially improve conditions. As nearly as can be determined, neither this work nor the stack gas control work was ever utilized by the ship building community probably because it was conducted by the aircraft

community. The problem is perhaps even more severe now with the increasingly common marriage of aircraft systems with non aviation ships, so it is to be hoped that this approach may be utilized to seek improvements to the present marginal conditions under which helicopters are too often forced to operate.

e) Arresting Gear and Catapult Studies - Files 15, 16, 17, 18, 19, 20, 21, 32, 37, 41, 42, 43, 46, 47, 49, 50

Dr. Ringleb made many basic contributions to arresting gear development by producing an analysis of the dynamics of cables. Less well known, but displaying considerable ingenuity and insight is his work on valves, water breaks and various forms of catapults ranging from a study of a reversed arresting gear used as a slingshot to one utilizing water jets to achieve constant acceleration. His work in these areas seems to be well known, well regarded and, more importantly, used.

As can be seen by looking over Table II, Dr. Ringleb's interests ranged over many other topics, but for the most part he picked these as interesting examples of the areas of his fundamental concern. With the possible exception of the work he did on the underwater launch of missiles dealt with in Folder 14 which drew some attention from the Polaris designers, most of his work on these topics was for his own edification.

CONCLUSIONS AND RECOMMENDATIONS

This review and evaluation of the work of Dr. F. O. Ringleb failed to disclose any specific areas requiring the development of further research programs. However, the areas of his basic interest, flow visualization and vortex motion, are of as great significance today as at the time of his death and further work in them is continuing in many areas.

The following recommendations are made:

- a) Every effort should be made to see that the work Dr. Ringleb did on the flow about ships and on the control of stack gasses is brought to the attention of the Naval Sea Systems Command, not so much to affect the design of carriers as to demonstrate the value of the technique and the importance of aerodynamics in the design of non-aviation ships employing LAMPS.
- b) The Naval Air Systems Command librarian should check Tables I, and II in order to determine that copies of Dr. Ringleb's major works are on file. Except as a possible source to supply missing items, the folders themselves are not of archival importance and may be destroyed.
- c) Many of the photographs are of outstanding quality, but without detailed information regarding test conditions are of little

practical value. The most significant ones have been included in Dr. Ringleb's publications. Although the originals are of better quality than the reproductions there is little need to retain this incomplete collection which may also be destroyed.

Although the findings of this report may seem very negative, it must be pointed out that Dr. Ringleb, working with small and inexpensive facilities, managed to make significant contributions to a very rapidly moving field. In a sense, the fact that the leads his work opened up have for the most part been followed up is a testimony to his selection of important problems.

It may seem regrettable that Dr. Ringleb's facilities have been dismantled, but with the passing of this keen observer and analyst of physical phenomena, the truly significant element of this laboratory was lost. It is unlikely that the quality and originality of the work could have been maintained without him.

TABLE I

Published Works of Dr. F. O. Ringleb

1. On the Conformal Mapping of Polygons, Diss. Jena 1926.
2. On the Number of Values of the Functions Which Transform Polygons into the Halfplane, Rend. del Circ. Mat. di Palermo.
3. On the Conformal Mapping of Simply Connected Areas by Algebraic Functions, Math. Zeitschr. 1929.
4. On Two Dimensional Potential Flows Through Cascades, Zeitschr. angew Math u. Mech. 1931.
5. Contributions to the Theory of Functions in Hypercomplex Systems, Rend. del Circ. Mat di Palermo 1933.
6. On the Behavior of the Curvature of Plane Curves at Conformal Mapping, Jahresber di Deutschen Math. Ver. 1935.
7. Exact Solutions of the Differential Equations of an Adiabatic Gas Flow, Zeitschr. angew Math u, Mech. 1940.
Abstract in the Journal of the Royal Aeronautical Society, Vol. 46, 1942.
8. On the Differential Equations of an Adiabatic Gas Flow and the Limiting Line, Deutsche Mathematik, 1940.
9. Approximate Method of Determining the Pressure Distribution of an Adiabatic Gas Flow, ZWB FB 1941.
Translation A9-T-5, Brown University, 1948.
10. Contributions to Profile Classification, F. B. 1941
ME/GE/RE/64 ATI 39852.
11. Some Aerodynamic Relations for an Airfoil in Oblique Flow,
FB No. 1497, Oct. 1941 SER/FB/1497 ATI 22543

12. Contributions to the Theory of Airfoils, Jahrbuch der Luftfahrtforschung, 1942.
13. Minimum Take-Off Distance With Rocket Assist, ZwB, FB, Oct. 1943 ZwB/LEA/5043/239 ATI 26947.
14. Iteration Method for Determining the Velocity Distribution of an Airfoil I, II, Jahrbuch der Luftfahrtforschung, 1943, 1944.
15. Numerical and Graphical Methods of Conformal Representation, ZwB, FB 1964 May 1944 ATI 38629
16. Thin Profiles With the Smallest Resistance of Circulation, Jahrbuch der Luftfahrtforschung, 1944.
17. Theory of the Heated Gas Flow, Part of: Fundamentals of Lorin-Propulsion, U. S. Navy, Bureau of Aeronautics, Washington, 1946.
18. Computation of a Ramjet With Straight Combustion Chamber, NAMC, Report No. M4684, 1947.
19. Friction of a Cable on a Cylinder, NAMC, Report No. M4750, 1948.
20. Dynamics of a Moving Cable, NAMC, Report No. M4812, 1948.
21. Control of H8 Catapult Brake Pressure, NAMC, Report No. M4899, 1949.
22. Computation of the Laminar Boundary Layer with Suction, Journal of the Aeronautical Sciences, Vol. 19, No. 1, 1952.
23. Dynamics of a Hydraulic Jet Catapult With Automatic Jet Control, NAMC, Report No. M5231, 1952.
24. Cable Impact at a Moving Sheave, NAMC, Report No. M5622, 1953.
25. Preliminary Report on Circulation Control by Means of Trailing Edge Suction and the Cusp Effect (D. C. Hazen, R. F. Lehnert, T. E. Sweeney and F. O. Ringleb), Princeton University Aero Eng'g Dept. Report No. 234, 1953.

26. Circulation Control by Means of Trailing Edge Suction
(D. C. Hazen, T. E. Sweeney, R. F. Lehnert and
F. O. Ringleb), Princeton University Aero Report
No. 239, 1953.
27. Investigation of Hose Vibrations of an Inflight Refueling System,
NAMC Report No. M6040, 1955.
28. Double Wire Engagements at Aircraft Arresting Gears, NAMC
Report No. M5927, 1955.
29. Flow Control by Generation of Standing Vortices and the Cusp
Effect, Princeton University Dept. of Aero. Eng'g Report
No. 317, 1955.
30. Investigation of Suction Flaps, Princeton University Dept. of
Aero. Eng'g Report No. 304, 1955.
31. Summary of Information and Data on Cable Dynamics, NAMC
Report No. M5933, 1955.
32. Basic Considerations on the Development of Aircrafts Arresting
Gear, Part of: NAMC Report No. M6070, 1956.
33. Cable Dynamics, NAMC Report NAEF-ENG-6169, 1956
34. Motion and Stress of an Elastic Cable Due to Impact, Journal of
Applied Mechanics, Vol. 24, No. 3, 1957.
35. Water Tunnel Model Investigations of Steam Catapult Launching
Valves, NAMC Report NAEF-ENG-6263, 1957.
36. Some Aerodynamic Relations for the Airplane Wing in Yawed Flow,
North American Aviation Inc., Report No. NA-46-448 (No Date)
37. Determination of the Strap Lengths in a Nylon Energy Absorber,
NAEF (SI) - ENG -6344.
38. Smoke Control Studies for CVA-59 Class Aircraft Carriers,
NAEF (SI)-ENG-6399, 1958.

39. Determination of the Velocity Field of an Airfoil With Leading Edge Suction, In: Mississippi State Univ. Aerophysics Dept. Res. Rpt. No. 22, 1959.
40. Flow Phenomena Associated With the Underwater Launching of Missiles, NAEF (SI) - ENG - 6466, 1960.
41. Two-Dimensional Flow With Standing Vortices in Ducts and Diffusers, Journal of Applied Mathematics, 1960.
42. Separation Control by Trapped Vortices, In: Boundary Layer and Flow Control, Vol. edited by V. Lachmann, Pergamon Press, London, 1961.
43. The Three Dimensional Smoke Tunnel of the Naval Air Engineering Laboratory in Philadelphia, Pennsylvania, NAEL-ENG-6818, 1961.
44. Contributions to the Geometry of Flow, NAEL-ENG-6754, 1961.
45. Smoke Control by Means of Cyclone Generators, NAEL-ENG-6871, 1962.
46. Studies of the Airflow Over an Aircraft Carrier, NAEL (SI)-ENG-6923, 1962.
47. Cable Dynamics, In: Handbook of Machine Design and Mechanical Systems, edited by H. Rothbart, McGraw-Hill Book Co., 1962.
48. Geometrical Construction of Two-Dimensional and Axisymmetrical Flow Fields, AIAA Journal, Vol. 1, No. 10, 1963.
49. Vortex Motion, Mississippi State University Aerophysics Dept. Res. Rpt. No. 47, 1963.
50. Three-Dimensional Smoke Tunnel Studies of the Wind Over the Deck of an Aircraft Carrier, NAEL-ENG-7019, 1963.
51. Smoke Control Studies for the USS Norton Sound (AVM-1), NAEL-ENG-7018, 1963.

52. Discussion of Problems Associated With Standing Vortices and Their Applications, In: ASME, Fluids Eng'g Div. Conf. Symposiums on Fully Separated Flows, Philadelphia, Pa., 1964.
53. Considerations on the Maneuvering of a Small Submersible Near a Submerged Body in the Presence of a Current (F. O. Ringleb and E. T. Kornowski), In: Automatic Control in Space, Vol. 2 Proceedings of 2nd International Conference, Vienna, 1967.

TABLE II

Ringleb File Inventory

1. Smoke Tunnel - Notes and Photos

Measurements and sketches of elements of three dimensional wind tunnel segments of a report entitled: The Three Dimentional Smoke Tunnel of the Naval Air Engineering Laboratory in Philadelphia, Pa. by F. O. Ringleb.

Also Photographs CAN	297511	-	No date
	326924	-	5 Feb. '60
	326925	-	" "
	326926	-	" "
	326927	-	" "
	334687	-	7 Mar. '61
	334688	-	" "
	334689	-	" "

Some material on smoke generation from Collins Radio, design of contraction cone and rough theory of smoke lines (incomplete). Also contains copy of preprint of Considerations on the Maneuvering of a Small Submersible Near a Submerged Body in the Presence of a Current by E. T. Kornowski and F. O. Ringleb.

2. Vortex Flow Studies and the Applications to the Solutions of Navy Problems

Four lecture cards giving basic equations and characteristics of three dimensional vortex flow.

Also Photographs CAN	322275	-	21 Aug. '61
	339457	-	20 Sept. '61
	339458	-	" "
	339464	-	" "
	339581	-	" "
	341599	-	4 Jan. '62
	341602	-	" "

343304	-	23 Mar. '62
343327	-	" "
343331	-	" "
345567	-	11 Jul. '62
344886	-	12 Jul. '62
344898	-	" "
339466	-	20 Sept. '62
352061	-	6 May '63
370081	-	28 Jul. '65
370095	-	" "
370100	-	" "
370101	-	" "
370105	-	" "
371279	-	30 Sept. '65
374074	-	7 Mar. '66

plus one small unmarked or dated photograph of flow past streamlined carrier island.

3. Vortex Motion, Notes

A copy of the 35 page version of Two-Dimensional Flow With Standing Vortices in Ducts and Diffusers apparently as originally issued as NAEF-ENG-6656. The remaining notes, figures and calculations apparently resulted from the preparation of the text of Vortex Flows.

4. Smoke Control by Means of Cyclone Generators

The handwritten text of Smoke Control by Means of Cyclone Generators including the printed photographs of Fig. 2 and 3 as they appear in the report.

Also Photographs CAN	335138	-	30 Mar. '61	
	339466	-	so Sept. '61	(2 copies)
	341599	-	4 Jan. '62	"
	341602	-	" "	"

5. Smoke Ejector Proposal

This is a proposal to study a smoke ejector utilizing either a shield or a pulsated ring vortex to prevent the smoke from being drawn down behind the smokestack. This proposal, stapled into the folder contains

Photographs CAN	305398	-	26 Sept. '57
	305397	-	" "
	305391	-	" "
	305395	-	" "

6. Flight Path Carrier Air Flow

Copies of a series of calculations labled "R. Perry, Flight Path Computations" plus a number of sheets of similar calculations in F. O. Ringleb's handwriting. The approach appears to be to represent the flow over the stern of the carrier as influenced by a standing vortex. There are also lists of the photograph numbers used as figures in Three Dimensional Smoke Tunnel Studies of the Wind Over the Deck of an Aircraft Carrier, NAEL-ENG-7019 and in Smoke Control Studies for the USS Norton Sound (AVM-1) NAEL-ENG-7018.

7. Effects of the Configuration of an Aircraft Carrier on Aircraft

Contains the typed draft of a paper entitled Effects of the Configuration of an Aircraft Carrier on Starting and Landing Aircraft. No date is given but the references cited indicate that it must be post August 1964. Lists of photograph numbers are given but the figures are not included. The paper explains how individual flow singularities are used to simulate the flow field about an aircraft carrier producing potentially deleterious effects. An airfoil shaped island is proposed.

8. Carrier Air Flow, Data, Letters and Notes

Copy of February 1963 Approach containing an article on ramp strikes. Typewritten draft of Three Dimensional Smoke Tunnel Studies of the Wind Over the Deck of an Aircraft Carrier. Numerous notes, rough graphs and sketches of carrier and deck air flow geometry.

9. RSSH - 33/001/200/9 Carrier Air Flow Analysis

Copy of WEPTASK No. RSSH - 33/001/200/9 authorizing smoke tunnel studies of carrier deck air flow.

Also Photographs CAN	335601	-	20 Apr. '61
	335602	-	" "
	335603	-	" "
	339577	-	26 Sept. '61
	339578	-	" "
	339580	-	" "
	339582	-	" "
	339583	-	" "
	339584	-	" "
	339585	-	" "
	339586	-	" "
	339587	-	" "
	339588	-	" "
	339592	-	" "
	339593	-	" "

10. Meeting, 6 Jan., Wash., Carrier Air Flow

Notes on background of carrier approach problem. Proposed narration of movie showing effect of carrier configuration changes on surrounding flow field.

11. Carrier Air Flow, NAEL-ENG-7019

Letter referring to film Three Dimensional Smoke Tunnel Studies of Wind Over Deck on an Aircraft Carrier. Copies of various graphs labeled "Turbulence Profile - CVA-67."

12. Studies of the Air Flow Over

Typed draft of Studies of the Air Flow Over an Aircraft Carrier, NAEL (SI)-ENG-6923. Typed text of Note on the Air Flow Over an Aircraft Carrier. Rough notes and contractual details.

13. Water Tunnel for Flow Visualization of Cavitation

Copy of ONERA paper Tunnel Hydrodynamic a Visualization. Rough design calculations for water tunnel and copy of Engineering Order dated 14 May '65 directing its construction.

14. Underwater Phenomena

Letters relating to and copy of Proposal For Studies of Flow Phenomena Associated With the Underwater Launching of Missiles. Handwritten notes Flow Phenomena Associated With the Underwater Launching of Missiles, the commentary to precede a showing of a film. Also a series of figures giving dimensions of Polaris missile, geometry of launching arrangements and underwater trajectories of both missile and generated vortices.

15. Sling Shot Catapult - Notes and Comp.

Calculations, neglecting elastic effects, of the dynamics of a sling shot catapult consisting of a cable reeved over two sheaves attached to a mass that is accelerated by pulling the cable ends. Incomplete and uncorrected rough draft of paper entitled Dynamics of a Sling Shot Catapult dated 20 August 1962.

16. Tape Catapult and Arr. Gear Sling Shot Catapult

Rough calculations for various geometries of slingshot catapults. Original of a brief note entitled Nylon Tape Friction Clutch Catapult dated March 6, '61. Calculations relating to pressure-energy relationships of liquid rotating between two drums.

17. Terry's Arresting Gear

An analysis of a two mass system representing an arresting gear is outlined in rough form, methods of solution are indicated and two sets of results plotted.

18. Envelope containing original copy of paper Basic Problems in the Dynamics of the Aircraft Arresting Gear. No date or report number indicated. A straightforward and readable discussion of the dynamics of arresting gears.

19. Water Jet Catapult II

Copy of a typed document dated 20 October 1953 entitled Proposal of a Simplified Hydraulic Jet Catapult. Numerous handwritten calculations relating to the performance of hydraulic catapults. Handwritten copy of Memorandum on Hydraulic Jet Catapult Investigations and Tests dated 12 May 1955 describing results of Saunders and Thomas tests and proposing the nature of continued tests. A number of drawings of proposed water jet catapult schemes. Memo dated 12 October 1954 commenting unfavorably on a proposal submitted by United States Research of Trenton for hydro-jet catapult studies.

20. Barrier

A set of five figures showing various configurations of barriers under test with actual aircraft and dead loads. These sets apparently taken from reports but they are not identified. One set of sketched graphs showing tension and run-out vs ram travel for a variety of test conditions.

21. Catapulting of Missiles

This folder contained the original copy of Note on the Effectiveness of Catapulting a Missile, the background calculations for which are contained in Folder #32 Rocket Mechanics.

22. Jet Pump

Photocopy of Jet Pumps With Liquid Drive, R. G. Folsom, Chemical Engineering Progress, Oct. '48. A series of hand-written calculations for various jet pump configurations based on The Pumping Characteristics of Long Mixing Section Jet Pumps, N. L. Fox, Report SM-14385, Douglas Aircraft, Santa Monica Division, 5 Sept. '52. Drawings of proposed jet pump model - drawings undated.

23. Hose-Roller

Copy of typed memorandum dated 8 April 1958 from E. Seidenglanz describing the results of burst pressure tests on 6" Dia. fire hose.

24. Stagnation Point Flow, Compressible - Other Exact Solutions

Handwritten numerical solutions of adiabatic flow relationships.

25. Computation of the Laminar Boundary Layer With Suctions

Typed copy of an undated manuscript entitled Computation of the Laminar With Suction with a subscript noting that it was a report to the Office of Naval Research, Washington. Notation on the outside of the folder indicates this was the basis of the Journal of the Aeronautical Sciences article of the same title that appeared in 1952.

26. Conformal Maps

Inked drawings of various mappings - stagnation flow, doublet in free stream, Joukowski airfoil, etc.

27. Vertol Flexible Rotor

Correspondence ranging from 9 April 1963 to 15 March 1965 relating to some rotor flow visualization tests requested by Vertol. Also photographs showing test rotor arrangement - No flow photographs included.

Photographs CAN	356958	-	13 Dec. '63
	356959	-	" "
	356960	-	" "
	356961	-	" "
	356962	-	" "

28. Mirror Stabilization

Two copies of handwritten drafts of Derivation of Roll and Pitch Correction Factors for the Point-in-Space Stabilization Used With Either the Mirror or Fresnel Lens Optical Landing System, NAEL-ENG-6865, Dec. 1961 by M. J. Giordano, with supporting data and computations along with a copy of a memorandum authorized by Dr. F. O. Ringleb dated 12 Jan. 1962 entitled Comments to the Report NAEL-ENG-6865 suggesting relatively minor changes.

29. Membrane Theory

A literature search covering the period 1951 to 1961 into the subject of Membrane Theory. Photocopies of several of the papers cited and some handwritten derivations of the equations relating to dynamic membrane stresses.

30. Lift Due to Jet Blast

Copies of three patents: No. 1,071,053, Burner for Combustible Gases, C. M. Hunter, Aug. 26, 1913; No. 2,613,067, Device for Introducing Atomized Liquid into Gas Under Pressure, H. J. Goodyer, Oct. 7, 1952; No. 2,717,637, Fuel Supply Apparatus for Resonant Pulse Jet Combustion Device, L. R. Huber, Sept. 13, 1955. Single plot labeled 3 Dimensional Doublet Near Boundary.

31. Air Curtain Literature

Photocopies of: How to Design Hot Air Door Curtains, L. F. Crouse, Air Engineering, Oct. '61; All About Air Entrances, E. J. Kurek, Air Engineering, June 1962; Wind Tunnel Tests Help Design Air Curtain Entrance, N. Zehnder, Heating, Piping and Air Conditioning, Dec. '60.

32. Rocket Mechanics

Handwritten calculations of rocket and orbital mechanics. Typewritten manuscript dated 4 May '61 entitled Note on the Effectiveness of Catapulting a Missile in which it is concluded to be effective, the catapult would require a performance comparable to that of the missile itself.

33. Dr. Drake, University of Kentucky, Lexington, Kentucky

Copies of correspondence and list of problems suitable for student projects.

34. Vivian O'Brien, Johns Hopkins University

Copies of correspondence from '61 to '66 relating to mechanics of viscous vortex flows.

35. Wave Resistance

Photocopy of The Effect of Shallow Water on Wave Resistance, T. H. Havelock, Oct. 28, '21

36. Wave Resistance

Photocopy of Wave Resistance: Some Cases of Three-Dimensional Fluid Motion, T. H. Havelock, Nov. 27, '18.

37. Measurement of Elasticity

Handwritten numerical data relating to measurements of the Modulus of Elasticity of several different sizes and types of cables.

38. Norton Sound Project

Drawings and sketches used in preparation of model for smoke tunnel testing. List of photographs taken and used in Smoke Control Studies for the USS Norton Sound (AVM-1), NAEL-ENG-7018, 1963.

39. Bell Aerosystems

Copy of Bell Aerosystems publications: Rendezvous, Vol. IV, No. 4, 1965 and Report No. 7223-953001, March 1965, V/STOL Capability.

40. Kellett Aircraft - Papers

Copy of publication entitled Downwash Presentation, Bureau of Naval Weapons, Department of the Navy, Washington 25, D. C., 19 June 1963.

41. Valves

Copy of Westinghouse Electric Corp. Report ASE Technical Report No. 662 WEC 7" Air Control Valve, Flow Model Test, S. O. 1258-A-705-230, V. G. Guins and V. H. Carder, 17 July 1959. Copy of Test Progress Report Model Studies of Retraction Valve P/N 55-50521-1, E. F. Stockinger, 16 April 1958. Copy of paper entitled Valve Flow Study, F. O. Ringleb, no date.

42. Slack Problem - AG Impact

Photocopy of The Velocity of Logitudinal Waves in Cylindrical Bars, D. Bancroft, Physical Review, April 1941. Copies of test results on various arresting gears compared to theoretical predictions taken from Cable Dynamics, NAMC Report NAEF-ENG-6169.

43. TM 24 - Impact Problem

Copy of letter SE-731:RCD: o, 13810 from Commanding Officer, Naval Engineering Center to Chief, Bureau of Naval Weapons dated January 11, 1963 describing aircraft damage history with XTM-20 arresting gear and the changes made converting it to the TM-24. Test result plots are included.

44. Trenton Thrust Augmenter

Copy of Rensselaer Polytechnic Institute, Department of Aeronautical Engineering and Astronautics TR AE6202 Crypto-Steady Pressure Exchange by J. V. Foa. Copy of Preliminary Analysis of a New Type of Thrust Augmenter, a paper presented by K. H. Hohenemser of McDonnell Aircraft Corp., at 4th National Congress of Applied Mechanics, U of Cal., Berkely, Cal., June 18-21, 1962. Copy of letter from Hohenemser to Ringleb dated June 17, '63 enclosing some preliminary test data.

45. Profiles With Chordwise Constant Velocity Distribution

Manuscript of Profiles With Constant Velocity Distribution with notation indicating that it is a report to ONR communicated first at a lecture about profile theory and conformal representation at Mississippi State College, 17 Oct. 1949.

46. Simplified Arresting Gear Equations

Copy of text and figures of Simplified Equations of the Motion and Tension of an Arresting Gear Cable. This is indicated as being NAF MISC 06350 but no date is shown.

47. Basic Problems in the Dynamics of the Aircraft Arresting Gear

Two copies of the text Basic Problems in the Dynamics of the Aircraft Arresting Gear with the notation that it appeared in "A Decade of Basic and Applied Science in the Navy" Washington, D. C., 1957.

48. Fluid Mechanics

A collection of calculations of fundamental fluid mechanical relationships, isentropic flows and viscous effects. Handwritten references to works on fluid mechanics. Sketches of observed vortex flow patterns. Also two photographs apparently taken in a water tunnel.

Photographs CAN	325318	-	8 Dec. '59
	325321	-	" "

49. Shock and Vibration of Wire Rope Arrestment of Airplanes

Copy of the paper Shock and Vibration in Wire Rope Arrestment of Airplanes, Ladislaus J. Fila, Oklahoma Institute of Technology, Oklahoma A&M College, Stillwater, Oklahoma, 13 August, 1952.

50. Miscellaneous Papers

Copy of manuscript entitled Note on the Evaluation of the Stresses in an Elastic Cable Due to Oblique Impact with a notation that this was presented as a technical lecture on 20 Dec. '57. Copy of a proposal entitled Research and Development Proposal for Water Brakes dated 10 Dec. '54. Two photocopies of a paper entitled Comment to K. Razak's Paper on "Recent Developments in Boundary Layer and Circulation Control at the University of Wichita," no date shown. A one page note Theory of Injection dated 30 April '51. A three page note entitled Theoretical and Experimental Investigations on the Flow Control Effect of a Cusp by D. C. Hazen and F. O. Ringleb, no date given. Two copies of a 12 June '51, 2 page letter to A. Raspet. A copy of a four page letter to A. Raspet dated 2 Nov. '50 and its handwritten original. Both letters discussed boundary layer and flow control problems then being studied at Mississippi State and at Princeton. Two incomplete copies and one complete one of a 20 Oct. '52 Technical Note from F. O. Ringleb to the Chief Engineer entitled Barrier Adapter Problem. Three copies of an undated 6 page note entitled Advantages of a Collaboration Between Universities and Naval Research and Development Activities. Copy of a note dated 28 May '51 on Review of a British Investigation Concerning Cable Dynamics and Aircraft Arresting Gears. A two page note dated 3 April '51 labled Two-Dimensional Potential Flow Investigations About Trailing Edge Suction.

51. Geometry of Flow

Handwritten notes, calculations and plots of a variety of two and three dimensional potential flows.

52. Isentropic Flow Over Edge

Handwritten calculations and plots augmented with computer print-outs of the solution of isentropic flow about various two-dimensional inlet shapes.

TABLE III

Photograph

<u>No.</u>	<u>Date</u>	<u>Description</u>
297511	----	Spanwise flow in vortex formed in cusp of finite length.
325318	8 Dec. '59	Water flow past valve element made visible by stream of dye.
325321	8 Dec. '59	Water flow past valve element - dye in different position.
326924	5 Feb. '60	View of three dimensional smoke tunnel showing honeycomb.
326925	5 Feb. '60	View of three dimensional smoke tunnel showing transition section downstream of test section.
326926	5 Feb. '60	View of three dimensional smoke tunnel test section showing carrier island model mounted.
326927	5 Feb. '60	General view of three dimensional smoke tunnel showing configuration.
334687	7 Mar. '61	Flow past FBM submarine with slight yaw to port.
334688	7 Mar. '61	Flow past FBM submarine at greater angle of yaw showing vortex shed by sail.
334689	7 Mar. '61	End view of flow past FBM submarine at large angles of yaw showing shed body vortices.
335138	30 Mar. '61	End view of cusp flow similar to that shown in 297511.

335601	20 Apr. '61	Flow over carrier deck. Wind off port bow.
335602	20 Apr. '61	Flow over carrier deck. Wind off port bow.
335603	20 Apr. '61	Flow over carrier deck. Wind off star-board bow.
322275	21 Aug. '61	Vortex pair under suddenly moving rectangular plate.
339457	20 Sept. '61	Not identified.
339458	20 Sept. '61	Flow over an edge.
339464	20 Sept. '61	Symmetrical, Straight airplane wing with wing tip vortex.
339466	20 Sept. '61	Three dimensional "cyclone" smoke control stack.
339577	26 Sept. '61	View of carrier island with cambered plate to decrease circulation.
339578	26 Sept. '61	Carrier deck cross flow. Wind off port bow. No island.
339580	26 Sept. '61	Carrier deck edge flow. Forward port side. Wind off port bow.
339581	26 Sept. '61	Port side deck edge vortex more clearly shown.
339582	26 Sept. '61	Carrier deck cross flow showing edge vortex.
339583	26 Sept. '61	Tip vortex shed from streamlined island at angle of yaw.
339584	26 Sept. '61	Tip vortex shed from streamlined island at angle of yaw.

339585	26 Sept. '61	Streamlined island with flap to control circulation.
339586	26 Sept. '61	Flow past rectangular island at angle of yaw.
339587	26 Sept. '61	Streamlined island with circulation control flap.
339588	26 Sept. '61	Streamlined island with circulation control flap.
339592	26 Sept. '61	Flow past rectangular island at angle of yaw.
339593	26 Sept. '61	Flow past rectangular island at angle of yaw with circulation control flap.
339594	26 Sept. '61	Flow past carrier island with circulation control flap.
341599	4 Jan. '62	Conventional smokestack.
341602	4 Jan. '62	Conventional smokestack with "cyclone" generator applied at top of stack.
343304	23 Mar. '62	Core of wing tip vortex in flow over edge.
343320	23 Mar. '62	Parallel Flow.
343331	23 Mar. '62	Wake and glide path of carrier with streamlined island under zero angle of attack.
344886	12 Jun. '62	General view of flow about carrier.
344898	12 Jun. '62	Side view of flow past carrier showing effect in glide path.
345567	11 Jul. '62	Cusp configured island.
352061	6 May '63	Airflow over CVA 59 (Forrestal) island under angle of attack.

356958	13 Dec. '63	General view of Vertol rotor model hub.
356959	13 Dec. '63	General view of Vertol rotor model and drive system.
356960	13 Dec. '63	Detailed view of Vertol rotor swash plate.
356961	13 Dec. '63	Detailed view of Vertol rotor swash plate.
356962	13 Dec. '63	General view of Vertol rotor model.
370081	28 Jul. '65	Flow over the bow of carrier.
370095	28 Jul. '65	Flow over triangle under angle of attack.
370100	28 Jul. '65	Stagnation vortex of Forrestal island in cross flow from portside.
370101	28 Jul. '65	Stagnation vortex in front of flat plate.
370105	28 Jul. '65	Stagnation vortex entrapped in cusp.
371279	30 Sept. '65	Flow over triangle under moderate angle of attack.
374074	7 Mar. '66	Flow over triangle at high angle of attack showing vortex "bursting."